Neutron shielding for the CBM silicon tracker

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The CBM experiment is designed as a multi-purpose device which will be able to measure hadrons, electrons and muons in heavy-ion collisions. The core detector of the CBM setup is a Silicon Tracking System (STS) located in the gap of a superconducting dipole magnet. Electrons will be identified with a Ring-Imaging Cherenkov Detector (RICH), a Transition Radiation Detector (TRD), and a Time-of-Flight Detector (ToF). In order to measure muons the RICH will be replaced by Muon Tracking Chambers (MuCh). The MuCh consists of 6 hadron absorbers and tracking stations in between. The first 20 cm iron absorber is located 5 cm behind last silicon tracking station. FLUKA [1, 2] calculations predict an increased non-ionizing energy loss (NIEL) level in the STS with the muon setup.

The main reason for the increase of the NIEL level is back-scattered neutrons from the hadron absorber. This was studied with a simple model presented in Figure 1. It consists of the CBM target (250 μm Au foil), the magnet, and the beam pipe. The neutron flux at the position of the last STS station (see scoring plane in Fig. 1) was calculated with and without 20 cm iron absorber. The neutron distributions are shown on Figure 2 (blue and red lines). The number of neutrons increases up to 10 times if the hadron absorber was put in. In order to shield the neutrons from the absorber a borated polyethylene layer was placed between the scoring plane and the iron. The neutron distributions with 5 cm neutron shielding for different fractions of boron are presented in Figure 2 (light blue and green lines). The number of neutrons decreases up to 4 times if a 5 cm 5% borated polyethylene layer was put between the scoring plane and the iron. Figure 3 shows the NIEL distribution in the last STS layer for the electron setup (right), for the muon setup (left), and for the muon setup with the neutron shielding (middle). The NIEL level decreases substantially if the neutron shielding is used.

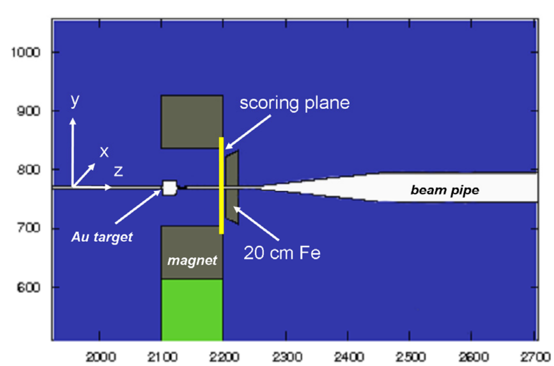

Figure 1: the FLUKA geometry for neutron shielding optimizations.

The FLUKA study demonstrated the possibility to shield neutrons from the iron absorber. The 5 cm 5% borated polyethylene layer allows to reduce the NIEL level in the last STS station by a factor of up to five.

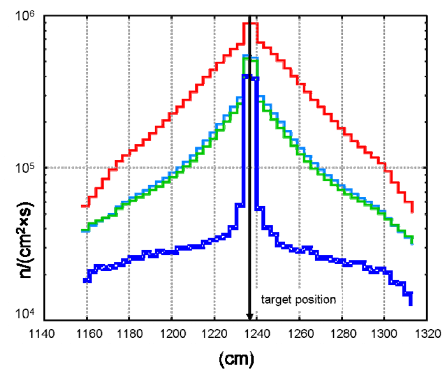

Figure 2: neutron distributions in the position of the last STS station calculated with FLUKA. Blue line – without 20 cm iron absorber, red – in front of the absorber without neutron shielding, light blue – with 5 cm 5% borated polyethylene layer, and green – with 5 cm 30% borated polyethylene.

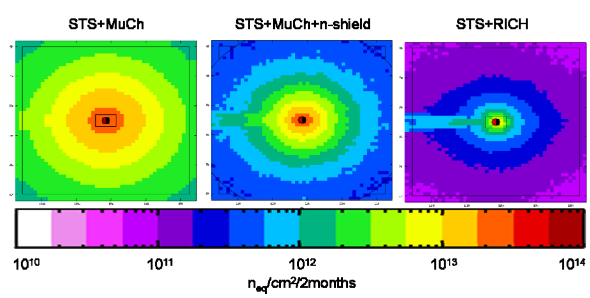

Figure 3: NIEL distributions in the last STS station for 35 GeV/u Au beam after 2 months of run with an intensity of 10^9 ions per second for the electron setup (right picture), for the muon setup with 5 cm neutron shielding (middle), and for the muon setup without shielding (left).

References

[1] "The FLUKA code: Description and benchmarking", G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A. Ferrari, S. Roesler, A. Fasso`, J. Ranft, Proceedings of the Hadronic Shower Simulation Workshop 2006, Fermilab 6-8 September 2006, M. Albrow, R. Raja eds., AIP Conference Proceeding 896, 31-49, (2007)

[2] "FLUKA: a multi-particle transport code", A. Fasso`, A. Ferrari, J. Ranft, and P.R. Sala, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773